James Webb Space Telescope: The First Light Machine

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ABSTRACT

Scheduled to begin its 10 year mission no sooner than 2013, the James Webb Space Telescope (JWST) will search for the first luminous objects of the Universe to help answer fundamental questions about how the Universe came to look like it does today. At 6.5 meters in diameter, JWST will be the world’s largest space telescope. This talk reviews science objectives for JWST and how they drive the JWST architecture, e.g. aperture, wavelength range and operating temperature. Additionally, the talk provides an overview of the JWST primary mirror technology development and fabrication status.
Origins Theme's **Two** Fundamental Questions

- How Did We Get Here?
- Are We Alone?

**How Did We Get Here?**

*Trace Our Cosmic Roots*
- Formation of galaxies
- Formation of stars
- Formation of heavy elements
- Formation of planetary systems
- Formation of life on the early Earth

**Are We Alone?**

*Search for life outside the solar system*
- Search for other planetary systems
- Search for habitable planets
- Identify remotely detectable bi-sigatures
- Search for "smoking guns" indicating biological activities

**Missions Supporting the Origins Goals**

**JWST Summary**

- **Mission Objective**
  - Study origin & evolution of galaxies, stars & planetary systems
  - Optimized for near infrared wavelength (0.6-28 μm)
  - 5 year Mission Life (10 year Goal)
- **Organization**
  - Mission Lead: Goddard Space Flight Center
  - International collaboration with ESA & CSA
  - Prime Contractor: Northrop Grumman Space Technology
  - Instruments:
    - Near Infrared Camera (NIRCam) - Univ. of Arizona
    - Near Infrared Spectrometer (NIRSpec) - ESA
    - Mid-Infrared Instrument (MIRI) - JPL/ESA
    - Fine Guidance Sensor (FGS) - CSA
  - Operations: Space Telescope Science Institute

**JWST Requirements**

- **Optical Telescope Element**
  - 25 sq meter Collecting Area
  - 2 micrometer Diffraction Limit
  - < 50K (~35K) Operating Temp
- **Primary Mirror**
  - 6.6 meter diameter (tip to tip)
  - < 25 kg/m² Areal Density
  - < $4 Mln² Areal Cost
  - 18 Hex Segments in 2 Rings
  - Drop Leaf Wing Deployment
- **Segments**
  - 1.315 meter Flat to Flat Diameter
  - < 20 nm rms Surface Figure Error

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**A Vision for Large Telescopes & Collectors**

**Toward Accomplishing... the Impossible!**

- 100-1000m diameter
- 20-40m diameter
- ~10m diameter
- 2.4m diameter
- JWST, HST, SAFIR

**JWST Operational Development Conceptual Unimaginable**
AMSD - Ball & Kodak

OTL Architecture Concept

Investments Have Reduced Risk

JWST Technology Demonstrations for TNAR

Advantages of Beryllium

OTL Specifications

Diameter: 1.4 meter point-to-point
Radius: 10 meter
Area Density: < 20 kg/m2
Areal Cost: < 544$/m2

Beryllium Optical Performance
- Ambient Fig: 47 nmm (initid)
- Ambient Fig: 20 nmm (bulk)
- 290K ~ 30K: 77 nmm
- 35K ~ 30K: 7 nmm

ULE Optical Performance
- Ambient Fig: 38 nmm (initid)
- 290K ~ 30K: 188 nmm
- 35K ~ 30K: 20 nmm

JWST Primary Mirror Segment

Very High Specific Stiffness – Modulus/Mass Ratio
Saves Mass – Saves Money
High Conductivity & Below 100K, CTE is virtually zero.
Thermal Stability

Technology Development of Large Optical Systems

OTL is the JWST Primary Mirror Blank Technology Development Lead for OTL

Figure Change: 30-55K Operational Range

Beryllium

Surface Figure With Alignment Compensation

ULE Glass

Residual with 36 Zernikes Removed

Figure Change: 30-55K Operational Range

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Mirror Manufacturing Process

Blank Fabrication

Machining

Polarizing

Mirror System Integration

Brush Wellman
Status = Flight Mirror Lightweighing Complete

Satys Technologies

PWSA Engineering Development Unit

Axsys Technologies

8 AON Machining Centers

Movie

Fabrication Process

Substrate Fabrication
XRCF Facility Upgrades in FY '05-06

JSC Chamber A Thermal Vacuum Facility

JSC Chamber A
Chamber size: 55' diam, 117' high
Existing Shrouds: LN2 shroud, gHe panels
Chamber Cranes: 4x25t fixed, removable
Chamber Door: 40' diam
High bay space: ~102'L x 71'W

XRCF CCS Assembly

1 of 3 Shrouds rough cleaning
1 of 3 floors move into clean room
Shrouds move into clean room

XRCF CCS Fit-Check

JWST I&T

JSC “Cup Up” Test Configuration

JSC Size, Accessibility, and Large Side Door Access
Make it Well Suited for This Configuration

JWST Launch and Deployment

- JWST is folded into stowed position to fit into the payload fairing of the Ariane V launch vehicle
- Several subsystems deploy during transit to its L2 orbit
When and how did reionization occur?

Reionization happened at z=6 or 1 billion years after Big Bang.

WMAP says maybe twice?

Probably galaxies, maybe quasar contribution

JWST Observations:
Spectra of the most distant quasars
Spectra of faint galaxies

First Light: Observing Reionization Edge.

Lya Lyman-Alpha

First Light: What did the first stars galaxies to form look like?

We don't know, but models suggest first stars were very massive!

Infrared Light

Light from the first galaxies is redshifted from the visible into the infrared.

The Hubble Deep Field

How do we see first light objects?

Deep Imaging: Look for near-IR drop-outs

First galaxies are small & faint

Light is redshifted into infrared.

Low-metallicity, massive stars.

JWST Observations

Ultra-Deep NIR survey (1.4 uJy), spectroscopic & Mid-IR confirmation.

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New Results from UDF

How do we see first light objects?
The first stars may be detected when they became bright supernovae. But, they will be very rare objects!

The Renaissance after the Dark Ages
Hubble Ultra Deep Field

Sensitivity Matters
GOODS CDFS – 13 orbits
HUDF – 400 orbits

The Hubble Sequence
Hubble classified nearby (present-day) galaxies into Spirals and Ellipticals.
The Hubble Space Telescope has extended this to the distant past.

Where and when did the Hubble Sequence form? How did the heavy elements form?
Galaxy assembly is a process of hierarchical merging
Components of galaxies have variety of ages & compositions
JWST Observations:
NIRCam Imaging
Spectra of 1000s of galaxies

Distant Galaxies are "Train Wrecks"
### Unusual objects

- Proto-stellar clouds collapse

### Birth of Stars and Proto-Planetary Systems

- How do proto-stellar clouds collapse?
- How do stars form in small regions collapsing gravitationally within larger molecular clouds?
- How do environment affect star-formation?
- Massive stars produce wind & radiation that disrupt star & planet formation, or cause it to proceed differently or at a different rate. Boundary between smallest brown dwarf stars & planets is unknown.

### Solar System

- How do planets form?
- How are circumstellar disks like our Solar System?
- Giant planets could be signposts of a process that creates Earth-like planets and comets.

### JWST Observations

- Deep NIR and MIR: Imaging of dark clouds, revealing temperature and density structure.
- How are circumstellar disks like our Solar System?
- Comparing spectra of comets & circumstellar disks...
**Planetary systems and the Origins of Life**

How are habitable zones established?

- Source of Earth's H₂O and organics is not known. Comets? Asteroids?
- History of clearing the disk of gas and small bodies. Role of giant planets?
- JWST Observations: Comets, Kuiper Belt Objects. Icy moons in outer solar system

**Atmospheres of Extrasolar Planets**

- Extrasolar Planet Transits
- Detecting terrestrial planet atmospheres

**Bio Markers**

Spectroscopic Indicators of Life

- Absorption Lines
- CO₂, Ozone, Water. "Red" Edge

**Countdown to Launch**

Planned for 2013 Launch

**Any Questions?**